Internal Government Studies

1995

Reports and Presentations

Study Name: Climate Study Suite

Team Members: NOAA/ORA(W. Planet),
NRL(R. Lucke), &
Univ. of MD(R. Hudson)

IPO POC: S. Mango

A

INTERNAL GOVERNMENT STUDIES - FY 1995
Climate Study Suite

Presentation/Paper Title	Author(s)	Date
"Final Report, Sensors for Solar Irradiance Monitoring"	J. Lean, P. Foukal, R. Lee III, C. Frohlick, H. Jacobowitz	1 OCT 95
"Workshop on NPOESS Ozone Measurements Requirements-Meeting Minutes"	W. Planet(summary)	30-31 AUG 95
"Climate Monitoring Suite ICS Final Presentation, Earth Radiation Budget, Solar Irradiance, Aerosols"	H. Jacobowitz	28 SEPT 95
"Climate Study Suite Final ICS Presentation to the IPO (with recommended IORD EDR Levels)"	R. Lucke, W. Planet R. Hudson	28 SEPT 95
"Climate Suite IORD Recommendations to the IPO, Report to the IPO (7 pages)."	All Team Members	28 SEPT 95
"Climate Monitoring Suite Study Report for the NPOESS ICS: Part A: Ozone Sensors"	R. Lucke, W. Planet R. Hudson	28 SEPT 95
"Climate Study Suite Final Report for NPOESS ICS: Part A, Ozone Sensors, DRAFT'	R. Lucke, W. Planet R. Hudson	31 AUG 95
"Climate Monitoring Suite, ICS Interim Status Presentation to the IPO (Earth Radiation Budget vu-graphs)"	H. Jacobowitz	29 JUNE 95
'Climate Monitoring Suite, ICS Interim Status Presentation to the IPO (OZONE SENSOR vu-graphs)"	R. Lucke, W. Planet R. Hudson	29 JUNE 95
"Climate Monitoring Suite, ICS Interim Status Presentation to the IPO (Solar Irradiance Sensor vu-graphs)"	J. Lean	29 JUNE 95
"NPOESS Ozone Workshop Proposal"	W. Planet	28 JUNE 95
"Cost Analysis Inputs (CARD) for Ozone Sensors for the NPOESS"	R. Lucke	I7 APRIL 95
"CARD Input for Climate Suite Internal Concept Study"	H. Jacobowitz	17 APRIL 95
"Ozone Sensor Study: Monthly Progress Report, AUGUST 95"	R. Lucke	8 AUG 95
"Ozone Sensor Study: Monthly Progress Report, JUNE 95"	R. Lucke	13 JUNE 95
"Ozone Sensor Study: Monthly Progress Report, MAY 95"	R. Lucke	16 MAY 95
"Ozone Sensor Study: Monthly Progress Report, APRIL 95"	R. Lucke	18 APRIL 95

Workshop on NPOESS Ozone Measurements Requirements

August 30-31, 1993
NOAA Science Center
Camp Springs, Maryland

Summarized by:

Walter G. Planet
NOAA/National Environmental
Satellite, Data, and
Information Services
Office of Research and Appl.
Satellite Research Laboratory

/

Executive Summary

A Workshop on NPOESS Ozone Measurements Requirements was held August 30-31, 1995, at the NOAA Science Center, Camp Springs, Maryland. The Workshop was sponsored by the Office of Research and Applications of the National Environmental Satellite, Data, and Information Service as part of an Internal Concept Study for the Integrated Program Office (ICS/IPO).

The purpose of the Workshop was to acquire scientifically-based ozone measurements requirements to be carried out by the National Polar-orbiting Operational Satellite System (NPOESS). These and other ozone-related requirements were to be presented to the IPO, to be considered in developing the operational satellite system payload.

Participants at the Workshop represented a scientific cross-section of users of satellite ozone data in a variety of studies including ozone trends and climate change. Participants were scientists from government agencies and universities in addition to the scientists carrying out the IPO study.

Highlights of the Workshop were:

1) Completion of requirements for the ozone Environmental Data Record (EDR) for the next version of the Interagency Operational Requirements Document (IORD).

2) Presentation and discussion of the final report of the Climate Suite Internal Concept Study conducted jointly by NOAA/Office of Research and Applications, DoD/National Research Laboratory and the University of Maryland, Department of Meteorology.

3) Recommendations and justification for measurements other than ozone but related to ozone photochemistry and climate effects. These measurements include stratospheric aerosols N_2O, stratospheric and upper tropospheric water vapor, ClO (or $ClONO_2$) and solar flux.

4) Agreement that user scientists must be involved in the instrumental aspects of the NPOESS definition process.

Extended Summary of the Workshop

Background

The Workshop on Ozone Measurements Requirements for ozone sensors in the NPOESS convened on August 30-31, 1993, at the NOAA facility in Camp Springs, Maryland.

The goal of the Workshop was to review and develop a consensus of the scientific community on the measurement requirements for ozone applicable to the next-generation operational system. NPOESS, the converged satellite system of the future, will become operational early in the next century. It will be designed to satisfy a host of operational requirements including long-term measurements for monitoring purpose.

Excerpts from the IORD were made available to the Workshop participants. These excerpts spelled out the then-current state of the operational requirements and the overall rationale for the measurements. Several elements of the ozone EDR were listed as TBD and the Workshop participants were asked to address the requirements.

Participants were asked to address ozone measurement requirements from their individual viewpoints and research needs. For those items listed as TBD, they were to recommend specific capabilities. Other parameters related to ozone (ie, other constituents and temperature) were also to be addressed. Participants selected were in the general category of "users" rather than "measurers." Emphasis was to be on operational measurement rather than research measurements.

A list of participants is given in Appendix 1.

The Workshop began with a brief overview of the NPOESS requirements process, schedules and the Internal Concept Study for the Climate Suite under the Integrated Program Office. As previously stated to the participants, the goal of the Workshop was to review and develop a consensus on the measurement requirements for ozone applicable to the next-generation NPOESS. The parameters for the ozone Environmental Data Record as contained in the Integrated Operational Requirements Document was noted to contain many TBDs. The Workshop participants were asked to address these requirements by supplying the missing parameters of the EDR as well as reviewing and changing the existing parameters.

Informal Presentations

Several participants gave individual presentations addressing different aspects of the Workshop objective. Not all are included with this Summary but all are listed in Appendix 2.

J. Kaye presented his thoughts on the need for ozone measurements. Based in part on past reports such as the **National Plan for Stratospheric Monitoring** (FCM.P17.1989) and **Spaced Based Ozone Measurements in the 21st Century** (from the Dulles, VA., meeting held in June 1994), several questions on the why and what of monitoring were presented and discussed. A summary of his recommendations follows:

o Converged program should include monitoring of ozone and related constituents

o Ozone measurements should include mapping of total ozone and improved measurement of vertical profile (stratosphere and troposphere)

o Enough other quantities should be monitored so that data can be interpreted, especially temperature, ClO, H_2O, aerosols, HNO_3, and possibly one dynamical tracer (N_2O?)

o Allowance should be made for related parameters (tropospheric aerosols, SO_2) and supporting applications (including very rapid access to data) where incremental costs are low

o The overall international measurement program should be significantly larger than the operational monitoring program to provide the full context for interpretation of measurements and continued validation of hypotheses.

L. Hood discussed his work with TOMS ozone data and the measurements requirements for ozone and related parameters, including temperature, solar UV spectral irradiance and geopotential height.

K. Bowman discussed the role of ozone in studies on transport and mixing in the stratosphere and requirements for ozone and other parameters in general

E. Remsberg discussed ozone measurements needs particularly as related to ozone profile accuracy (±3 to 5%) and temperature accuracy (±2k). Measurements should be extended into the mesosphere. Ozone and temperature profiles should have similar vertical resolution (3km or less).

J. Angell discussed long-term histories of total ozone and ozone vertical profiles. He pointed out some research issues with the latter especially concerning volcanic ash solar activity, QBO and El Nino effects.

L. Perliski discussed research in Global Circulation Modelling and the development of a fully-interactive GCM with detailed photochemistry.

R. Portmann discussed the role of aerosols and their variations in ozone depletion. He emphasized the depletion occurring in the northern mid-latitudes and in the springtime Antarctic. He noted that in order to interpret future ozone measurements, coincident aerosol measurements are essential.

S. Chandra discussed solar activity-ozone relations using stratospheric ozone distributions determined from SBUV/2 and MLS observations.

R. Lucke discussed the study sponsored by the NPOESS Integrated Program Office on the applicability of existing and planned ozone sensors. He specifically related sensor characteristics (cost, weight, power) as well as measurement performances as they all relate to the NPOESS measurements requirements. Included in the study report prepared for IPO were measurement parameters for several atmospheric species related to ozone photochemistry.

D. Wuebbles discussed the need for measurements of other constituents in order to better understand ozone. During the Workshop he prepared a note on recommendations and justification for ozone and other trace constituent measurements. This was expanded and combined into a note by **Perliski, Portmann** and **Wuebblee** which is Appendix 3 to this report.

Further general discussions

A vigorous discussion, both during the above presentations and following, was centered on the objective of the Workshop; ie. establishing the ozone measurement requirements for NPOESS. The then-existing table of requirements was modified, completed and clarified to generate a Workshop-endorsed table of requirements. This is given in Appendix 4. Subsequent to the Workshop, it was transmitted to the IPO. In addition to ozone, measurements of other atmospheric parameters were discussed particularly of stratospheric temperature and water vapor. After the Workshop measurements requirements were generated by A. Miller (temperature), D. Wuebbles (water vapor) and L. Hood (solar ultra-violet flux) given in Appendix 5. Measurement requirements for other species not covered in the Workshop are in the Internal Concept Study Report and include N_2O, ClO, $ClONO_2$ and HNO,.

APPENDIX 1

List of Participants

NAME	AFFILIATION
Walter Planet	NOAA/National Environmental Satellite, Data, and Information Service
Alvin Miller	NOAA/National Weather Service
Ellis Remsberg	NASA/Langley Research Center
Lori Perliski	NOAA/Geophysical Fluid Dynamics Laboratory
Kenneth Bowman	Texas A&M University
Lon Hood	University of Arizona
Beth Chertock	NOAA/Oceanic and Atmospheric Research
Richard Stolarski	NASA/Goddard Space Flight Center
Ernest Hilsenrath	NASA/Goddard Space Flight Center
Donald Wuebbles	University of Illinois
Eric Shettle	Naval Research Laboratory
Robert Lucke	Navel Research Laboratory
Jack Kaye	NASA
Robert Portmann	NOAA/CIRES
Susil Chandra	NASA/Goddard Space Flight Center
Robert Hudson	University of Maryland
Jim Angell	NOAA/Air Resources Laboratory

APPENDIX 2

Workshop Presentations

Appendix 2
Workshop Materials Presentations

J. Kaye — **Some thoughts on measurements of ozone and related atmospheric constituents for "convergence!**

L. Hood — **Measurement requirements for ozone and related parameters -** notes

K. Bowman — **Large-scale transport and mixing in the stratosphere -** notes

J. Angel1 — **Research issues -** notes

L. Perliski — **Long-term research plans -** notes

R. Portmann — The **Role of aerosol variations in anthropogenic ozone depletion -** notes

S. Chandra — notes

R.L. Lucke, W.G. Planet and R.D. Hudson **- Climate Suite Study Report for the NPOESS Internal Concepts Study - Part A: Ozone Sensors** (1995)

D. Wuebbles — **Recommendations and justifications for ozone and other trace constituent measurements -** note.

APPENDIX 3

Recommendations and Justification for Ozone and Trace Constituent measurements

L. Perliski, R. Portmann and D.J. Wuebbles

Recommendation and Justification for Ozone and Trace Constituent Measurements

Lori Perliski, Bob Portmann and Donald J. Wuebbles

1.0 Introductory Comments

NPOESS will play a critical role in monitoring the atmospheric and oceanic environments in the next century by systematically measuring a variety of climatically-important variables. Although about seventy measurement priorities, or environmental data records (EDRs), have been established, the currently planned measurements may not provide the opportunity to adequately monitor the future evolution of the ozone layer. The comments below result from a workshop aimed at achieving a consensus on requirements for NPOESS ozone measurements. Arguments are presented that elucidate the value of measuring other trace constituents in addition to ozone. The ability to interpret ozone measurements accurately will be considerably diminished without corresponding measurements of other trace constituents thought to be critical in influencing ozone levels. Of highest importance are aerosol abundances, as well as stratospheric water vapor and the dynamical tracer, N_2O, which would significantly enhance the ability to determine the effects of interannual dynamical variability on atmospheric ozone. Measurements of atmospheric trace species such as ClO, HCl, HNO_3, and NO_2 which are involved in the partitioning of chlorine between reactive and reservoir forms, would also be very useful. Depending on the type of ozone measurement system chosen by the NPOESS program, experience from the NASA UARS (Upper Atmosphere Research Satellite) Program has demonstrated that additional instrument channels may easily be added to measure these species for relatively little additional cost.

2.0 Ozone

Special consideration needs to be given to monitoring ozone abundances in the upper troposphere and lower stratosphere, therefore it is essential that the NPOESS ozone measurements be accurate in the upper troposphere and lower stratosphere. There are several underlying reasons for this priority:

1) The observed changes in total ozone over the last twenty years have largely been due to decreases in lower stratospheric ozone. Over the next few decades, the significant stratospheric ozone decreases due to CFC's and halons are predicted to decline as stratospheric chlorine abundances begin to drop. However, recovery of the stratospheric ozone layer is not expected to be largely complete until the middle of the next century, and will be dependent on the actual production and emissions of HCFCs and other replacement compounds, the extent to which the Copenhagen Amendment to the Montreal is followed, and the amount of methyl bromide released into the atmosphere.

2) Recently, the effects of existing and projected aircraft emissions on upper tropospheric and lower stratospheric ozone have been the subjects of intense research. These potential effects are not well understood at this time, but are of sufficient concern to warrant increased emphasis on accurate ozone monitoring in these regions. In addition, extensive use of next generation supersonic aircraft may begin around 2005, with probable flight altitudes in the 16-17 km altitude region of the lower stratosphere. While current models of atmospheric dynamical and photochemical processes do not project major changes in ozone from a fleet of as many as 500 of these HSCT aircraft, uncertainties in those models justify the need for monitoring of ozone in this region.

3) Several studies have shown that ozone changes in the upper troposphere and lower stratosphere (roughly 5-20 km) would have the most significant impact on radiative forcing of climate change. Monitoring is needed to establish whether there are trends in tropospheric ozone.

3.0 Stratospheric Aerosols

Stratospheric aerosols play a key role in the partitioning between unreactive reservoir forms of halogens and reactive species which destroy ozone. Heterogeneous reactions of the reservoir molecules $ClONO_2$, N_2O_5, HCl and $BrONO_2$ on the surfaces of stratospheric aerosols effectively convert unreactive chlorine and bromine to reactive forms while cycling nitrogen to HNO_3, a sink for the reactive stratospheric nitrogen. These heterogeneous processes are very temperature-dependent and rend to occur fastest at cold temperatures. However, heterogeneous chemistry is thought to be relatively efficient on stratospheric background liquid sulfate aerosols as well as Polar Stratospheric Clouds (PSCs). The presence of the background sulfate aerosol layer has likely increased the long-term ozone decrease at mid-latitudes due to increases in atmospheric chlorine and bromine. In addition, enhanced aerosol abundances due to volcanic eruptions cause large ozone depletion events, as observed after the eruptions of El Chichon in 1982 and Pinatubo in 1991. The lower stratospheric aerosol amounts have been highly variable during the period from the late seventies (when satellite aerosol measurements began) and the present and will likely remain so in the future. Direct measurement from satellite currently remains the only reliable way to obtain global estimates of stratospheric aerosol surface area and attendant effects on ozone.

A further argument for long-term monitoring of stratospheric aerosols is that although stratospheric ozone is expected to recover in the next century due to atmospheric halogen decreases, several factors could slow or even reverse this recovery. The stratosphere could cool, for example, as the troposphere warms due to increased carbon dioxide. A stratospheric cooling would accelerate the temperature-dependent heterogeneous conversion of nonreactive to reactive chlorine and bromine, and likely increase the frequency of PSC formation, perhaps accelerating lower stratospheric ozone loss at high latitudes. Another possibility is that the properties of the stratospheric aerosol layer itself could exhibit long-term behavior. Ground-based observations suggest that the sulfate aerosol abundance in the stratosphere may be increasing due to anthropogenic sulfur emissions. Stratospheric water vapor increases are also expected in the future, due to atmospheric methane tury. This workshop was very successful, and it is our opinion that more such events should be held. In particular, it is very difficult to come up with a set of measurement parameters without considering what types of instruments could possibly fill the requirements. Currently, the research community is supposed to recommend parameters of the system without considering the type of instrument that would best fill the requirements. The prospective contractors are then expected to propose a specific observing system which may then be rejected if it does not meet the requirements. At first this methodology may seem perfectly rational, however, it may be argued that the choice of the type of instrument may not be separated so remotely from the detailed scientific considerations! Filling in a table of parameters becomes more an exercise in writing up a wish list rather than a careful evaluation of research needs and accomplishments of past observing systems. A better way to proceed is allow discussion of past ozone measurement systems, carefully evaluating and comparing them in the context of their appropriateness for an operational satellite program. Scientists intimately familiar with such past successful instruments such as SBUV, TOMS, LIMS, SAGE, and MLS should discuss the advantages and weaknesses of the their systems in detail. Let's try to learn as much as possible from our past experiences! In addition, the possibility of using the proposed instrument to measure other stratospheric parameters (like the those discussed above) should also be weighed, since it is possible that additional atmospheric information could be obtained very economically. The type of observing system should be decided on by the SCIENTISTS based on detailed scientific criteria, and then contractor's bids should be solicited. This would ensure the maximum amount of scientific involvement in planning this program and it would increase the likelihood that we will get the most scientifically-useful measurements possible for the first half of the next century. In addition, it is very important that the NPOESS plans be related to planned ground-based monitoring programs. Consideration of ground-based measurement programs could possibly have implications for discussions of which stratospheric quantities NPOESS should monitor, as well as how they should be monitored. NPOESS offers an extremely valuable opportunity to monitor and study the stratosphere's photochemistry and climate over a relatively long period in the next century. The fact that the number of research satellite launches in the next century is highly uncertain, makes it essential that the planning for NPOESS be done as carefully and thoughtfully as possible.

tropospheric circulation. Because of its importance to climate, it is essential that monitoring of water vapor to at least 100 mb (about 15 km) be a high priority. Extending monitoring of water vapor to at least 20 km or higher would provide valuable information on changes occurring in the stratosphere, not only due to water vapor trends, but expected responses in ozone and other stratospheric constituents.

Recent studies at the University of Illinois indicate that active lidar measurements of water vapor from space could achieve extremely high accuracies (1-2%) in measuring upper tropospheric concentrations of water vapor. The energy requirements are sufficiently low that further examination of such techniques are warranted.

6.0 Chlorine and Nitrogen Compounds

There is overwhelming evidence that chlorine compounds are largely responsible for the ozone depletion from the mid-seventies to the present, and they are predicted to continue to deplete ozone until they decline to background levels (sometime in the middle of the next century). The monitoring of a chlorine radical species like ClO will allow the direct estimation of chlorine induced ozone loss. This would be extremely valuable for identifying additional ozone loss processes, and estimating the degree of chemical processing at polar latitudes. The measurement of a chlorine reservoir species (HCl or $ClONO_2$) would also be of value in the interpretation of polar ozone loss.

Global measurements of a nitrogen compound, such as NO_2 or HNO_3, would be of value in ascertaining the degree of heterogeneous conversion of nonreactive to reactive halogen-containing molecules. In addition, long-term measurements of nitrogen-containing compounds would enable the monitoring of atmospheric nitrogen trends due to increases in surface nitrogen sources and aircraft emissions. As discussed above, trends in stratospheric and upper tropospheric nitrogen have important implications for ozone decreases in the stratosphere and increases in the upper troposphere.

As pointed out earlier, chlorine and nitrogen-containing molecules such as ClO and NO2 may not appear to be extremely good candidates for long-term *monitoring* considering the rather limited (in comparison to ozone, for example) histories of satellite measurements of these molecules. However, depending on the type of instrument chosen for the NPOESS ozone measurement system, it may be possible to obtain measurements of these molecules fairly inexpensively with the same instrument. Considerations such as these should be taken into account when the ozone instrument is selected.

7.0 Some Editorial Comments

The goal of the recent NPOESS ozone workshop was to achieve a consensus on ozone measurement parameters such as accuracy and resolution, as well as defining the specific measurement needs of the stratospheric ozone research community early in the next century. This workshop was very successful, and it is our opinion that more such events should be held. In particular, it is very difficult to come up with a set of measurement parameters without considering what types of instruments could possibly fill the requirements. Currently, the research community is supposed to recommend parameters of the system without considering the type of instrument that would best fill the requirements. The prospective contractors are then expected to propose a specific observing system which may then be rejected if it does not meet the requirements. At first this methodology may seem perfectly rational, however, it may be argued that the choice of the type of instrument may not be separated so remotely from the detailed scientific considerations! Filling in a table of parameters becomes more an exercise in writing up a wish list rather than a careful evaluation of research needs and accomplishments of past observing systems. A better way to proceed is allow discussion of past ozone measurement systems, carefully evaluating and comparing them in the context of their [redacted]ss for an operational satellite program. Scientists intimately familiar with such past successful instruments such as SBUV, TOMS, LIMS, SAGE, and MLS should discuss the advantages and weaknesses of the their systems in detail. Let's try to learn as much as possible from our past experiences! In addition, the possibility of using the proposed instrument to measure other stratospheric parameters (like the those discussed above) should also be weighed, since it is possible that additional atmospheric information could be obtained very economically. The type of observing system should be decided on by the SCIENTISTS based on detailed scientific criteria, and then contractor's bids should be solicited. This would ensure the maximum amount of scientific involvement in planning this program and it would increase the likelihood that we will get the most scientifically-useful measurements possible for the first half of the next century. In addition, it is very important that the NPOESS plans be related to planned ground-based monitoring programs. Consideration of ground-based measurement programs could possibly have implications for discussions of which stratospheric quantities NPOESS should monitor, as well as how they should be monitored. NPOESS offers an extremely valuable opportunity to monitor and study the stratosphere's photochemistry and climate over a relatively long period in the next century. The fact that the number of research satellite launches in the next century is highly uncertain, makes it essential that the planning for NPOESS be done as carefully and thoughtfully as possible.

APPENDIX 4

Ozone Measurements Requirements

4.1.6.2.28 **Ozone Total Column/Profile (DoC).** Measurement of ozone concentration within a specified volume.

Systems Capabilities		**Thresholds**	**Objectives**
a. Sensing Depth (km)			
1. Total column		O-top of atmosphere	0- top of atmosphere
2. Profile		10–60	O-60
b. Horizontal resolution (km)			
1. Total column		50 at nadir[1]	50 everywhere[2]
2. Profile		250	250
c. Vertical resolution (km)			
1. Total column		N/A	N/A
2. Profile	0-10 km	N/A	3
	10–25 km	3	1
	25-60 km	5	3
d. Mapping (km)			
1. Total column		5	5
2. Profile		25	25
e. Range			
1. Total column		0.05-0.65 atm-cm	0.05–0.65 atm-cm
2. Profile	0–10 km	N/A	0.01-3 ppmv or 10^{11}–$3 \cdot 10^{12}$ cm-3
	10-60 km	0.1-15 ppmv or $3 \cdot 10^{9}$–10^{13} cm^{-3}	0.1-15 ppmv or $3 \cdot 10^{9}$–10^{13} cm-3
f. Precision[3]			
1. Total column		0.001 atm-cm	0.001 atm-cm
2. Profile	0–10 km	N/A	10%
	10–15 km	10%	3%
	15-50 km	3%	1%
	50-60 km	10%	3%

[1]In combination with the refresh requirement, this requirement means that footprints must be 50 km at nadir increasing as necessary to edge of the swath.

[2]This objective means constant size footprints across a swath.

[3]Precision in this context means the instantaneous repeatability due to noise, not long term-repeatability due to instrument drift.

g. Accuracy[4]			
1. Total column		0.015 atm-cm	0.005 atm-cm
2. Profile	0–10 km	N/A	10%
	10–15 km	20%	10%
	15–60 km	10%	5%
h Refresh (days)			
1. Total column		1	1
2. Profile		7	1
i Long-term calibration[5]			
1. Total column		1.0%	0.5%
2. Profile		2.0%	1.0%

[4]Accuracy may be limited by uncertainties in our knowledge of fundamental absorption/emission cross-section. The figures given here do include the error due to uncertainties in line strengths.
[5]Long-term calibration means the long-term repeatability of a measurement.

APPENDIX 5

Additional Measurements Requirements

Recommendation and Justification for Stratospheric Temperature Measurements

Alvin J. Miller, Melvyn E. Gelman, Shuntai Zhou

The requirements for temperature measurements as part of the stratospheric monitoring program is based on many factors. Because ozone photochemistry in the stratosphere is temperature dependent it is necessary to include temperature variability within the overall explanation of ozone changes. In the lower stratosphere, temperatures have even more significance in their role in the development of the stratospheric aerosols and Polar Stratospheric Clouds which have been shown to exacerbate the ozone depletion in the lower stratosphere by influencing the temperature-dependent heterogeneous conversion of nonreactive to reactive chlorine and bromine. This would increase the formation of Polar Stratospheric Clouds and further accelerate the ozone loss at high altitudes. Monitoring of temperatures, then, serves to aid understanding of observed ozone changes.

A second factor is the effect of ozone changes on observed temperatures. In the lower stratosphere, the observed ozone decrease of about -6% per decade has been shown to be associated with temperature decreases of about -0.5 degree per decade. This has several possible ramifications. It can effect the formation of lower stratospheric aerosols as described above. Also, stratospheric temperature changes can effect the radiative balance at the earth's surface, impacting the global warming effect. For example, a decrease of temperature in the lower stratosphere has the effect of reducing the infrared radiation to the earth's surface and contributing a small counter-effect to the global warming impact.

It must be stressed that while the current discussion of stratospheric monitoring is done within the context of ozone change, the buildup of atmospheric carbon dioxide leads to a significant signal of a tropospheric temperature increase and stratospheric temperature decrease with the latter several factors greater than the former. Thus, stratospheric temperature monitoring serves to examine and help explain the combined impacts and causes of observed changes in atmospheric ozone and carbon dioxide.

Finally, stratospheric circulations are closely related to, and can be derived from the temperature. It is important to understand the seasonal and interannual changes in the circulation because it plays a critical role in the transport processes of chemical species (including ozone and CFC's) and aerosols. The temperature measurements also provide an objective benchmark for stratospheric modeling studies.

Stratospheric Temperature Profile Requirements

Systems Capabilities	Thresholds	Objectives
a. Sensing Depth (km)	1 O-60	O-60
b. Horizontal resolution (km)	250	250
c. Vertical resolution (km)		
O-10 km	N/A	3
10-25 km	3	1
25-60 km	5	3
d. Mapping (km)	25	25
e. Range (K)		
O-10 km	N/A	160-340
10-25 km	160-340	160-340
25-60 km	160-340	160-340
f. Precision (K)		
O-10 km	N/A	0.5
10-25 km	1	0.5
25-50 km	1	0.5
SO-60 km	3	1.5
g. Accuracy (K)		
O-10 km	N/A	0.5
10-25 km	1	0.5
25-50 km	2	1
50-60 km	3	1.5
h. Refresh (days)	7	1
i. Long-term calibration (K)	0.5	0.5

Water Vapor Measurements Requirements -
Upper Troposphere/Stratosphere
D.J. Wuebbles

Systems Capabilities	**Thresholds**	**Objective**
Sensing Depth	8km - 60	8km - 60km
Horizontal Resolution	1-2° (-100km)	50km
Vertical Resolution (8km - 22km) (300mb - 30mb)	<2km	1km
(22km - 60km) (30mb - 0.01mb)	5km	2km
Mapping Accuracy	10km	5km
Measurement Accuracy	10%	5%
Refresh	3 days	1 day

MEASUREMENT REQUIREMENTS FOR SOLAR ULTRAVIOLET FLUX AND KEY STRATOSPHERIC METEOROLOGICAL PARAMETERS

L. Hood

1.0 Introduction

In the lower stratosphere where the ozone photochemical lifetime is long compared to dynamical transport time scales, the ozone abundance at any given season and geographic location is strongly influenced by meteorological conditions. Because most of the ozone column is at altitudes below 30 km, these meteorological conditions can play an important role in determining the total ozone value from day to day, month to month, and year to year. A knowledge of any possible long-term changes in lower stratospheric meteorological conditions is therefore necessary for evaluating the origin of ozone trends. It can be shown that two key parameters that are commonly measured, temperature and geopotential height, are especially valuable for this purpose. However, the long-term accuracy and precision that are needed for trend evaluations are not commonly achieved.

A second physical quantity that must be accurately known for a complete interpretation of ozone variability is solar ultraviolet spectral irradiance. Solar flux at wavelengths less than 242 nm is responsible for the production of ozone in the upper stratosphere via the photodissociation of molecular oxygen. The flux at wavelengths near 200 nm is known to vary by 6 to 8% over a solar cycle and there may be significant changes on longer time scales as well. A solar cycle variation of total ozone with a global mean amplitude of 1.5 to 2.0% has been detected in both satellite and ground-based data records (e.g., Chandra and McPeters [1994]; Angell [1989]; Hood [1996]; Zerefos et al. [1996]). Ground-based proxies for solar UV flux changes, while valuable on the solar cycle time scale, have not been validated on longer time scales. Consequently, direct measurements of solar UV variability are required for evaluating the origin of ozone interannual variability and long-term trends.

2.0 Meteorological Parameters

Observationally, it is well known that total ozone over a given geographic location tends to be larger when lower stratospheric temperatures are increased and when the geopotential heights of constant pressure surfaces in the lower stratosphere are decreased [Reed, 1950; Dütsch, 1969; Rabbe and Larsen, 1992; Henriksen and Roldugin, 1995]. For example, using data obtained over the former Soviet Middle Asia, Henriksen and Roldugin [1995] demonstrate a significant positive correlation between ozone column density and temperature at the 100 mbar level and a significant negative correlation between ozone column density and the heights of the 100 and 500 mbar levels. Using a simple transport model based on the ozone continuity equation and the thermodynamic energy equation, it can be shown that this observed tendency is a consequence of dynamical forcing, i.e. vertical and meridional air motions in the presence of spatial gradients of zonal mean ozone and temperature (e.g., Hood et al. [1996]). Specifically, on a given constant-pressure surface at a given geographic location, it is possible to derive a relationship between a dynamically forced ozone mixing ratio perturbation $\Delta r'$ and dynamically forced perturbations of temperature $\Delta T'$ and geopotential height $\Delta Z'$ of the form

$$\Delta r' = A\Delta T' - B\Delta Z'$$

where A and B are constants that are functions of the vertical and meridional gradients of zonal mean temperature and ozone mixing ratio and of zonal mean zonal wind. Thus, if the temperature and geopotential height perturbations can be accurately measured, it is possible to calculate an approximate value for the ozone mixing ratio perturbation at that level. Repetition of this procedure at a series of lower stratospheric levels then allows the dynamically forced total ozone perturbation to be estimated.

Long-term lower stratospheric geopotential height and temperature data are available from a variety of sources including the U. S. National Meteorological Center (e.g., Randel [1992]; Finger et al. [1993]); the European Center for Medium-Range Weather Forecasting (ECMWF); and from the Stratospheric Research Group at the Free University of Berlin [Pawson et al., 1993]. In addition, 50–150 mbar weighted mean temperatures have been derived from Channel 4 radiances of the MSU instruments on the NOAA operational satellites [Spencer and Christy, 1993]. Of these data sources, the MSU data and the Berlin data have been most extensively used for estimating lower stratospheric temperature and geopotential height trends [Labitzke and van Loon, 1993; 1994; Randel and Cobb, 1994; Pawson et al., 1993; Perlwitz and Graf, 1995]. The NMC and ECMWF data sets are not generally considered to have sufficient long-term stability in the lower stratosphere to allow trend evaluations.

From the standpoint of NPOESS, the above discussion underscores the need for accurate and precise long-term satellite measurements of lower stratospheric temperature profiles. The horizontal resolution, accuracy, and precision should be comparable to that of the MSU Channel 4 data but with much better vertical resolution. The observed MSU temperature trends near 100 mbar range from -4 to $+4$ K/decade at different locations in the northern hemisphere (e.g., Randel and Cobb [1994]). The temperature precision and accuracy measurement objectives (0.5 K) listed in Appendix 5 therefore appear to be marginally sufficient for trend evaluations. Although accurate satellite remote sensing temperature measurements at all levels in the troposphere and lower stratosphere would, in principle, allow the geopotential heights to be calculated, direct measurements of geopotential heights at several levels via radiosondes are a highly desirable supplement. A continuation of analyses similar to those carried out at the Free University of Berlin (at 100, 50, 30, and 10 mbar) is therefore recommended. Observed trends in 100 mbar geopotential height range from -60 to $+60$ m/decade. Precisions and accuracies sufficient to allow the detection of trends of this magnitude (approximately 10 m) are therefore recommended.

3.0 Solar Ultraviolet Radiation

Although variations of solar UV spectral irradiance have been directly measured on time scales up to and including the 11-year solar cycle, possible variations on longer time scales have not yet been measured. Current estimates for the change in solar UV flux near 200 nm from solar minimum to maximum are in the range of 6 to 8% [Donnelly, 1991; Cebula et al., 1992; DeLand and Cebula, 1994; Rottman and Woods, 1995]. Observational evidence for the effects of variable solar UV spectral irradiance on stratospheric ozone and temperature at low and middle latitudes has been obtained on both the solar rotation time scale (e.g., Hood [1986]; Keating et al. [1987]; Chandra [1986]) and on the solar cycle time scale (e.g., Angell [1989]; Chandra and McPeters [1994]; Hood [1996]; Zerefos et al. [1996]). On time scales longer than a solar cycle, solar UV irradiance changes have thus far only been estimated based on parameterizations of facular brightening and sunspot darkening (e.g., Lean et al. [1995]). In order to validate such estimates, direct measurements of solar UV flux changes from one cycle to the next are required.

A number of proxies for solar UV spectral irradiance variability have been developed using both ground-based and proxy data. On time scales longer than the solar rotation period, the Canadian 10.7 cm radio flux time series has been found to be highly correlated with solar UV variations near 200 nm [Donnelly, 1991]. The Mg II core-to-wing ratio, which requires satellite UV measurements near 280 nm, is a somewhat better proxy for UV variations at shorter wavelengths [Heath and Schlesinger, 1986; Donnelly, 1991; Cebula et al., 1992]. Although these proxies are probably adequate for time scales shorter than the 11-year cycle and for UV variations near 200 nm, direct measurements are still required for longer time scales and longer wavelengths. *Consequently, direct solar UV spectral irradiance measurements are an appropriate addition to the NPOESS ozone measurement requirements.* A long-term measurement precision of no worse than 1% at 200 nm can be suggested.

4.0 References

Angell, J. K., On the relation between atmospheric ozone and sunspot number, *J. Climate, 2*, 1404-1416, 1989.

Cebula, R. P., M. T. DeLand, and B. M. Schlesinger, Estimates of solar variability using the Mg II index from the NOAA-9 satellite, *J. Geophys. Res., 97*, 11613-11620, 1992.

Chandra, S., The solar and dynamically induced oscillations in the stratosphere, *J. Geophys. Res., 91*, 2719-2734, 1986.

Chandra, S. and R. D. McPeters, The solar cycle variation of ozone in the stratosphere inferred from Nimbus 7 and NOAA 11 satellites, *J. Geophys. Res., 99*, 20665-20671, 1994.

DeLand, M. and R. P. Cebula, The composite Mg II solar activity index for solar cycles 21 and 22, *J. Geophys. Res., 98*, 12809-12823, 1993.

Donnelly, R. F., Solar UV spectral irradiance variations, *J. Geomagn. Geoelect., 43*, Supplement, Part 2, 835-842, 1991.

Dütsch, H. U., Atmospheric ozone and ultraviolet radiation, *World Survey of Climatology*, vol. 4, D. F. Rex ed., Elsivia, 1969.

Finger, F. G., M. E. Gelman, J. D. Wild, M. L. Chanin, A. Hauchecorne, and A. J. Miller, Evaluation of NMC upper stratospheric analyses using rocketsonde and lidar data, *Bull. Amer. Meteor. Soc., 74*, 789-799, 1993.

Heath, D. and B. Schlesinger, The Mg 280 nm doublet as a monitor of changes in solar ultraviolet irradiance, *J. Geophys. Res., 91*, 8672-8682, 1986.

Henriksen, Kjell and V. Roldugin, Total ozone variations in middle asia and dynamic meteorological processes in the atmosphere, *Geophys. Res. Lett., 22*, 3219-3222, 1995.

Hood, L. L., Coupled stratospheric ozone and temperature responses to short-term changes in solar ultraviolet flux: An analysis of Nimbus 7 SBUV and SAMS data, *J. Geophys. Res., 91*, 5264-5276, 1986.

Hood, L. L., The solar cycle variation of total ozone: Dynamical forcing in the lower stratosphere, *J. Geophys. Res.*, submitted, 1996.

Hood, L. L., J. McCormack, and K. Labitzke, A dynamical source of zonal mean total ozone trends at northern midlatitudes in winter, *J. Geophys. Res.*, submitted, 1996.

Keating, G., J. Nicholson III, D. F. Young, G. Brasseur, and A. De Rudder, Response of middle atmosphere to short-term solar ultraviolet variations, 1, Observations, *J. Geophys. Res., 92*, 889-902, 1987.

Labitzke, K., and H. van Loon, A note on trends in the stratosphere: 1958-1992, *Wissenschaftlicher Bericht Nr. 5*, 10 pp., Inst. Meteor. Freie Univ. Berlin, Berlin, Germany, 1993.

Labitzke, K. and H. van Loon, A note on trends in the stratosphere: 1958-1992, *COSPAR Colloquia Series, 5*, 1994.

Lean, J., J. Beer, and R. Bradley, Reconstruction of solar irradiance since 1610: Implications for climate change, *Geophys. Res. Lett., 22*, 3195-3198, 1995.

Pawson, S., K. Labitzke, R. Lenschow, B. Naujokat, B. Rajewski, M. Wiesner, and R.-C. Wohlfart, *Meteorologische Abhandlungen, Band 7, Heft 3 Climatology of the Northern Hemisphere Stratosphere derived from Berlin Analyses. Part 1: Monthly Means*, Verlag von Dietrich Reimer, Berlin, 299 pp., 1993.

Perlwitz, J., and H.-F. Graf, On the statistical connection between tropospheric and stratospheric circulation of the northern hemisphere in winter, *J. Climate, 8*, 2281-2295, 1995.

Rabbe, øA., and S. H. H. Larsen, Ozone variations in the northern hemisphere due to dynamic processes in the atmosphere, *J. Atmos. Terr. Phys., 54*, 1107-1112, 1992.

Randel, W. J., Global atmospheric circulation statistics, 1000-1 mbar, *NCAR Tech. Note NCAR/TN-366+STR*, 256 pp., Natl. Cent. for Atmos. Res., Boulder, Colo. 1992.

Randel, W. J. and J. B. Cobb, Coherent variations of monthly mean total ozone and lower stratospheric temperature, *J. Geophys. Res., 99*, 5433-5447, 1994.

Reed, R. J., The role of vertical motions in ozone weather relationships, *J. Meteorol., 7*, 263-267, 1950.

Rottman, G. J., and T. N. Woods, Solar ultraviolet irradiance: Variation from maximum to minimum of solar cycle 22, IUGG XXI Abstracts, p. B234, paper presented at

International Union of Geodesy and Geophysics XXI General Assembly, Boulder, CO, July, 1995.

Spencer, R. W. and J. R. Christy, Precision lower stratospheric temperature monitoring with the MSU: Technique, validation, and results 1979-1991, *J. Climate, 6*, 1194-1204, 1993.

Zerefos, C. S., K. Tourpali, B. R. Bojkov, D. S. Balis, B. Rognerund, and I. S. A. Isaksen, Solar activity - total ozone relationships: Observations and model studies with heterogeneous chemistry, *J. Geophys. Res.*, submitted, 1996.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA,
AND INFORMATION SERVICE
Washington, D.C. 20233

January 17, 1996

Dear Colleague,

Enclosed is a summary of the NPOESS Ozone Measurements Requirements Workshop held in August 1995. Please excuse my delay in preparing and disseminating it. ~~I have also included a copy of the report of the Internal Concept Study for IPO.~~

Every attempt was made to include the relevant information generated at the Workshop. I did not include reproductions of the vu-graphs because it would have required the speakers to prepare something approaching an extended abstract to make sense. If anyone does want copies, I will make them available.

Your cooperation in making the Workshop a valuable input to the NPOESS program is acknowledged and has been recognized by NOAA management. YOU probably will be reconvened as the program develops.

If you have comments on this Summary, please let me know.

Enclosures

Sincerely,

Walt Planet

Walter G. Planet
Chief, Physics Branch

38